

## Passive solar design Looe Junior and Infant School



- In nearly every respect the school achieves a high standard of environmental provision
- A 'low tech' traditional design optimises sunlight, daylight, and natural ventilation
- The school cost no more than average yet achieves a very good energy performance
- Solar energy contributes over a quarter of the space heating requirement



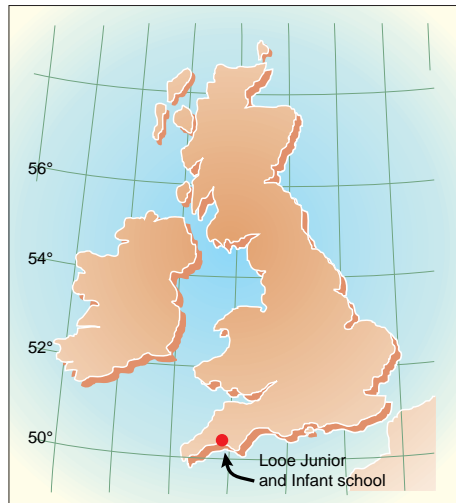
ENERGY EFFICIENCY

### Background

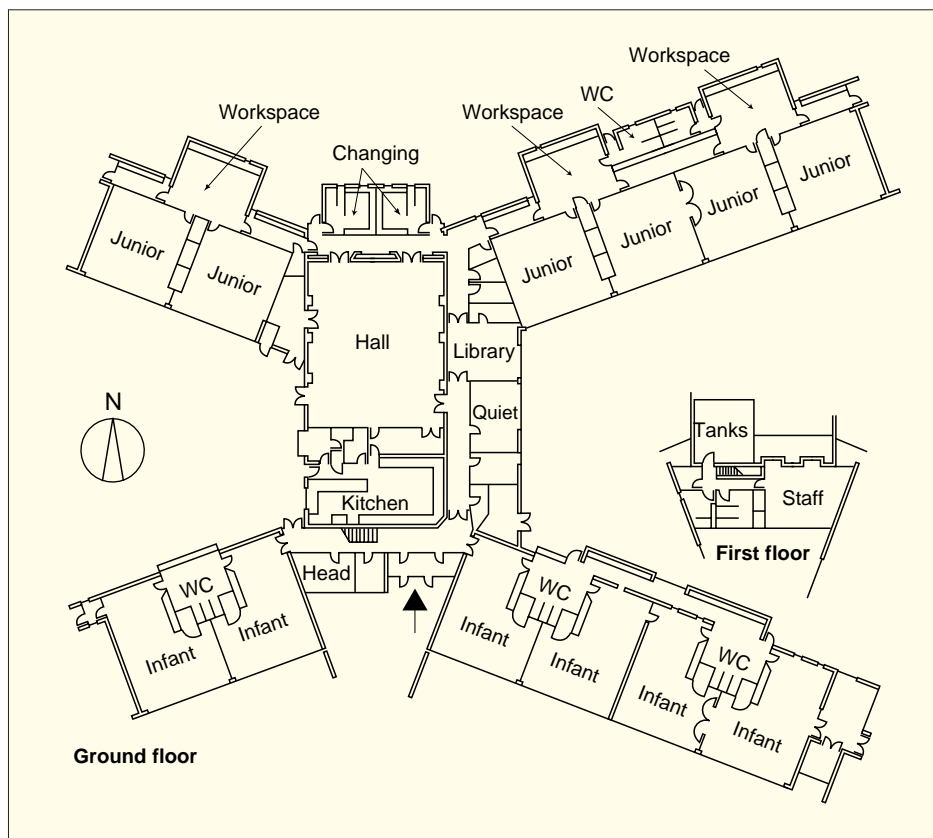
Looe Junior and Infant School has been designed to provide facilities for 300 children between the ages of four and eleven. It had, at the time of monitoring, four infant (now increased to six) and six junior classrooms, staff accommodation, ancillary services and catering facilities. It has been occupied since September 1984.

The school is the product of Cornwall County Council's desire to reduce its dependency on fossil fuels. In pursuit of this aim the architects decided that significant energy savings could be achieved in the school without substantially increasing capital cost. This was to be achieved by introducing passive solar features into a design which retained the use of familiar construction techniques.

Although Cornwall has a low annual degree-day total the exposed nature of the site, on a hilltop overlooking the sea with strong Atlantic winds, required careful planning with appropriate choice and location of materials.



Location of Looe



Plan of school: all classrooms face towards the south to take advantage of solar energy

### Design and solar strategy

Although the educational environment required by the briefing document was an important influence, the final plan was largely influenced by passive solar considerations.

The solar design strategy adopted for the school optimises solar gain by combining direct and indirect solar heating whilst minimising potential heat losses through the fabric. To achieve this, the following measures were used.

### Orientation

The school exploits direct solar gain in all the classrooms by placing them in a splayed plan, thereby providing each classroom with a large southerly facade. This plan arrangement also reduces overshadowing of the north wings by those to the south.

### Internal layout

Corridors and utility areas are placed along the north sides of the splayed arms and the hall, kitchen, library and staff rooms are contained in a central two-storey block. Access to classrooms is via the central block or draught lobbies on the north facade.

### Thermal mass

Masonry construction and a 'Trombe bench' design are used to accumulate heat gains in the structure so that they are released over time.

### Solar gain

Large areas of south facing glazing allow direct gain of solar radiation into the classrooms.

### High efficiency envelope

Use of high levels of insulation, avoidance of potential thermal bridging problems, and limitation of ventilation heat losses by a combination of draught lobbies and well sealed, draughtstripped windows.

### Daylight

Daylight is provided mainly by the large south facing windows augmented by south facing rooflights to illuminate the middle of the deeper infant classrooms and the workspace at the rear of the junior classrooms.



View from east: splay of infant and junior classrooms creates shelter for playground. North elevations only have small windows

### Controlling solar gains

The majority of the glazing is placed on the south facade to optimise the potential for solar heat gains for a given fabric heat loss. Taking the building as a whole, glazing accounts for 15% of the external wall area and 80% of it is on the south side of the school.

To control solar gains through the large areas of glazing in the classrooms, attention has been given to the form and choice of materials used in these areas. Roof eaves have a 750 mm overhang and there are internal venetian blinds to control the solar gains through the large south facing glazing.

To the outside observer the walls are a completely glazed facade, but internally only 60% of the glazing is visible from the classroom, the rest being Trombe bench. These work surfaces, in the form of tiled concrete worktops and concrete block walls to support it, behind the windows, have several purposes. Acting as mini Trombe walls, they absorb and store solar gains; function as a workbench; and isolate the pupils from the large area of glazing. The glazed cavity between the Trombe bench and the external glazing and ventilation pathways created by the bench were included to promote the circulation of warm air by natural convection currents.

The internal walls of cement-rendered blockwork increase the building's mass and further moderate heat gains and so even out temperature swings.

### Minimising heat losses

Both specification of materials and careful supervision of the construction process were intended to minimise fabric and incidental heat losses. Walls facing north have traditional masonry insulated construction and small windows. The ceiling is well insulated and the floor has perimeter insulation to avoid thermal bridging. To reduce infiltration rates the building envelope has been well sealed and the double glazing set in high specification frames. The draught lobbies further reduce ventilation heat losses.



*Venetian blinds control glare in spring and autumn and are positioned to allow sunshine onto the workbench, but can interfere with material on top of it*



*Infant classroom: the rooflights bringing light to the rear of the rooms were appreciated*



*The Trombe bench has grilles underneath it and in the worktop along the window to allow air to circulate up the cavity. Display material needs to be kept clear of the grilles*



*South elevation of a classroom showing wide roof overhang and continuous windows with Trombe wall below. Planting is growing up and will result in reduced solar gain*

### Services Ventilation

The school is primarily naturally ventilated by opening the horizontally sliding, full-height windows – there are no trickle ventilators. The kitchen, cleaners store, staff shower and WC are mechanically ventilated.

### Electric lighting

Rows of fluorescent fittings running parallel to the windows supplement daylight from the large south facing windows and south facing rooflights. Such an arrangement means that each row of lights can be independently switched to take account of the available daylight. The average installed load is 12 W/m<sup>2</sup> gross floor area (GFA).

### Heating and hot water

Space heating is provided by three gas-fired boilers each rated at 68 kW output serving fan assisted convectors controlled by a central thermostat and an optimiser. Each classroom has its own thermostat, which is under the control of the teacher.

Domestic hot water is produced by a boiler/calorifier rated at 48.5 kW, independent from the space heating system.



**South facing rooflights allow light and heat into the juniors' workspaces, but do not open and overheating can occur**

### User reaction

The overall reaction of those who use Looe School is that the building is successful both aesthetically and environmentally, except for some reservations about the ventilation. The school provides a popular environment that is conducive to learning and therefore is judged to have satisfied educational criteria. Good energy performance has not been attained at the expense of amenity.

### Ventilation

The decision to reduce heat losses by minimising infiltration rates but also to use an inflexible window design, resulted in poor air quality in the school. Teachers experienced problems with odour and stuffiness which could only be cleared by opening the large south facing windows. However, the resultant draughts, caused by the strong winds on the exposed site, disturbed teaching material on or adjacent to the Trombe benches. Therefore staff were reluctant to open the windows and consequently natural ventilation rates of 1 to 2 ach were below the 2.5 ach needed to meet Department for Education and Employment (DfEE) standards. Moreover, infiltration levels measured overnight were found to be very low at only 0.2 to 0.4 ach. It was therefore not surprising that CO<sub>2</sub> levels were averaging over 1200 ppm with a peak above 3000 ppm. A recommended level would be around 800 ppm.

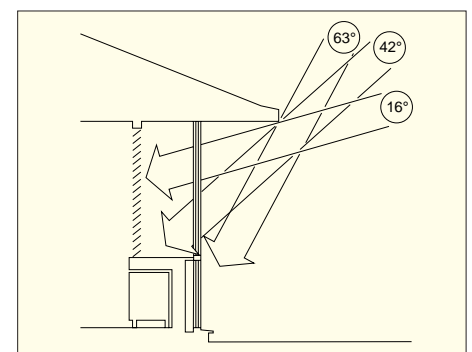
### Thermal comfort

The external shading and traditional masonry construction succeeded in preventing thermal discomfort to the occupants of the school for most occupancy periods. Several teachers felt they had occasionally experienced overheating in the school, but no underheating was reported.

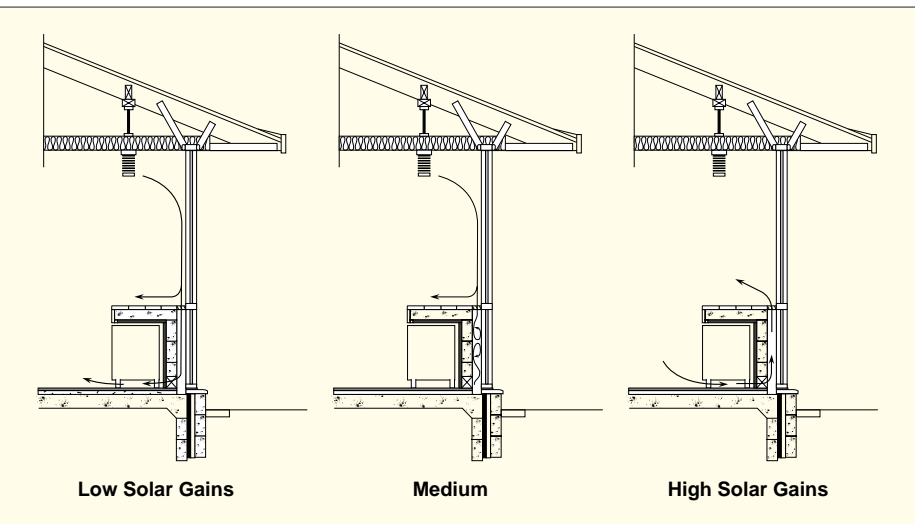
Classroom temperatures remained within a comfort range of 17 to 23°C for 88% of a one-year period, and temperatures over 27°C were recorded for only 9 hours over the whole school year. Better cross ventilation and avoidance of solar overheating could have been achieved by having opening rooflights and shading for them.

### Trombe bench

The Trombe bench contributed less to the building's performance than had been envisaged by the designer. Its relatively small area and limited mass meant that it accounted for only a small proportion of the total energy flow into each classroom – approximately 3% of the space heating energy.



**The overhang shades high angle sun with backup from venetian blinds for lower angles in the mornings, afternoons and spring and autumn**



**Air flow from the Trombe wall occurred on sunny days, but on less sunny days modelling indicated that a cold down draught from the windows stopped the warm air rising out of the cavity. When a window was opened for ventilation, heat could be quickly flushed out of the cavity and several days of sun required to restore a positive thermal gradient in the cavity**

### Construction

#### External walls $U = 0.43 \text{ W/m}^2 \text{ }^\circ\text{C}$

External walls are of traditional masonry construction with 100 mm facing brick, 50 mm cavity, 30 mm foil-lined insulation board, 100 mm medium weight blockwork and 12 mm render.

#### Floor $U = 0.3 \text{ W/m}^2 \text{ }^\circ\text{C}$

Floor finishes, on a 50 mm concrete screed laid on a 150 mm concrete slab, vary with activity. To avoid thermal bridging the insulation has been extended to a depth of 1 m beneath the floor slab.

#### Ceiling and roof void $U = 0.34 \text{ W/m}^2 \text{ }^\circ\text{C}$

The plasterboard ceiling is insulated with 100 mm foil-backed glass fibre quilt. To avoid thermal bridging the wall insulation has been continued into the roof space.

#### Windows DG $U = 4.0$ SG $U = 7.0 \text{ W/m}^2 \text{ }^\circ\text{C}$

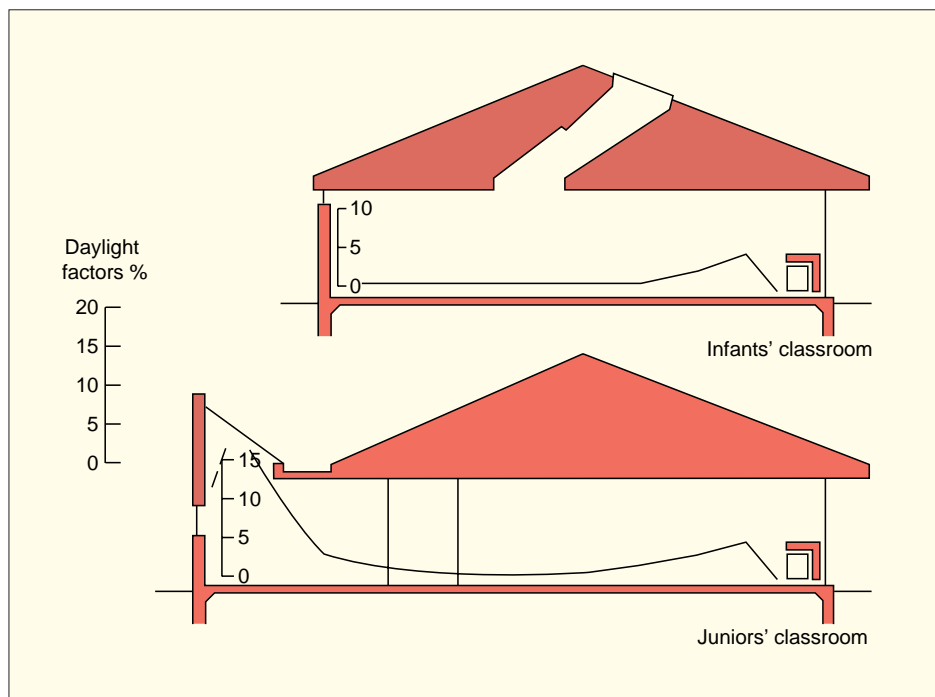
Due to the exposed nature of the site the main glazing units in the classrooms are high quality, aluminium framed, horizontally sliding, draughtstripped double glazed (DG) units. Small windows in the north and east facades are single glazed (SG) units in aluminium frames to reduce costs.

#### Rooflights DG $U = 4.0 \text{ W/m}^2 \text{ }^\circ\text{C}$

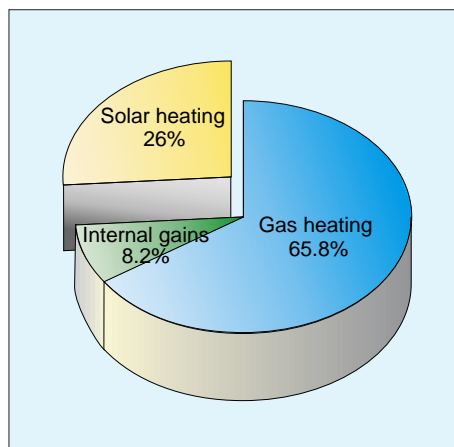
The south facing rooflights are double glazed.

#### Trombe bench

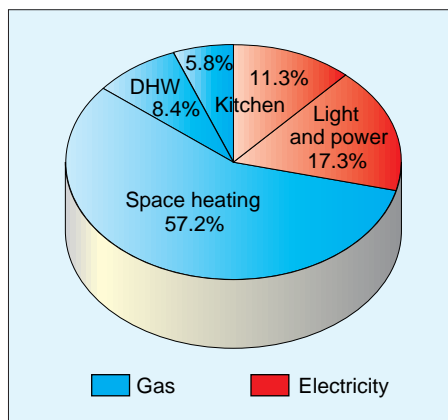
The thermally massive Trombe bench is the only non-standard construction in the building and is constructed from blockwork with a tile-covered concrete slab forming the bench.



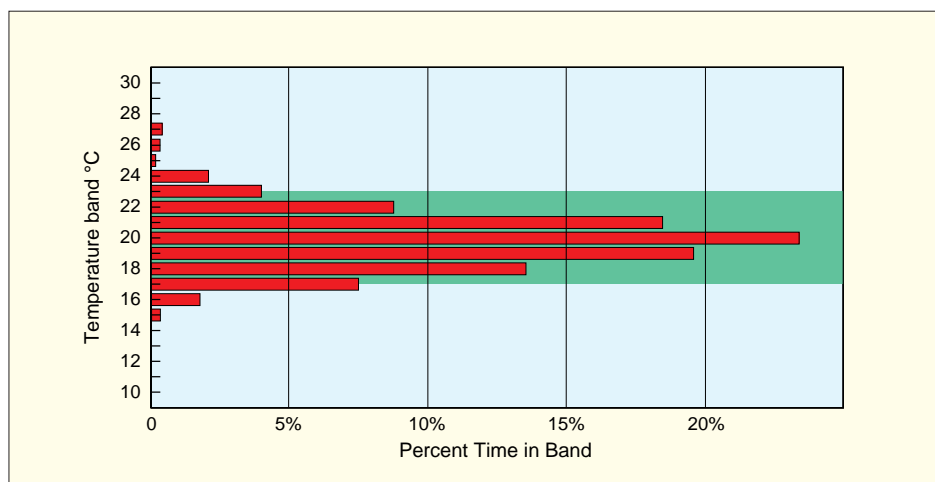
**Daylight factors:** the 750 mm roof overhang resulted in daylight levels rapidly decreasing to less than 2% within 4.5 metres from the window. The rooflights gave high light levels in the juniors' workspace but made little measurable difference to the infants' rooms



**Contributions to space heating**



**The annual primary energy use for the school was 347 900 kWh/year**



**Classroom temperatures were reasonable for most of the time. Any complaints of overheating seemed to stem from low angle morning or afternoon sunshine falling directly on teachers**

Whilst warm air circulation could occur on sunny days, this could be easily disrupted by down draughts from the windows and by opening of the windows. During periods of low solar radiation down draughts could also cause a reverse flow with cool air flowing across classroom floors.

The Trombe bench's other function as a worktop was often negated by draughts from open windows which disturbed displays on the bench.

### Daylighting

Whilst the large windows were appreciated for the views and sunshine, the 750 mm wide roof overhang did reduce the daylighting levels. Daylight factors dropped below 5% within the first metre of usable floor space and were around 2% for a large part of the room. Daylight was also reduced when the venetian blinds were down. As a result, the electric lighting was used for extensive periods.

In anticipation of reduced daylight, double glazed south facing rooflights were provided. Those over the workspaces of the juniors provided daylight factors of 10 to 20% and glare and excess solar gains sometimes resulted. Those over the infants' classrooms made surprisingly little difference to daylight factors when measured on an overcast day, although it was observed that they do help light the rear of the room at brighter times. They were also appreciated for giving character to the room by breaking up the plane of the ceiling.

### Analysis of energy use

During the year of monitoring, the heating demand occurred between the second weeks of October and May. Annual fuel use was 227 517 kWh delivered or 288 420 kWh primary energy (excluding kitchen use of 59 480 kWh primary).

	Delivered		Primary	
	kWh/m <sup>2</sup>	%	kWh/m <sup>2</sup>	%
Space heating	134.1	81	144.8	69
Water heating	19.8	12	21.4	10
Light and power	11.7	7	43.7	21
Total	165.6		209.9	

The school's figure of 210 kWh/m<sup>2</sup> compares very favourably with the DfEE Design Note 17 primary energy target of 247 kWh/m<sup>2</sup> for the same conditions. Part of the explanation for the low energy use is that solar gains shortened the heating season at both ends. There was a good correlation between solar radiation and heating energy use, with the major solar contribution coming from direct solar gain through the south facing windows and rooflights. The solar contribution (1778 kWh/week) to the gross total amount of energy needed to heat the school (6838 kWh/week) was 26%.

The Trombe bench was estimated to have contributed about 139 kWh/week to the solar contribution. By absorbing unwanted solar gains, it was estimated to reduce classroom peak temperatures by only less than 1 degree. That overheating in the school was not severe was mostly due to the shading of the windows and the heavyweight construction of the building. However, the bench's contribution to the thermal performance was positive compared with the alternative of opaque wall.



## CONCLUSION

### Construction costs

The capital cost of Looe School, normalised to the second quarter of 1986, was £417/m<sup>2</sup>. In comparison with other primary school construction costs, this is an average cost.

To counter the exposed location and to reduce maintenance, it was Council policy to use demanding specifications for cavity insulation, draught exclusion and double glazing, thereby increasing the cost of the school. The passive features have not added to the building cost except in the case of the roof. Here the cost was higher than average – some 17% of the building cost. This was partly due to the rooflights and the wide overhang, which added extra roof area.

However, the cost of the services installed was lower than normal, particularly in relation to the smaller size of the heating plant due to the low energy design.

### Lessons from this study

With a direct gain strategy, care has to be taken over orientation and shading. The designer provided a roof overhang and blind and, anticipating that these would reduce daylight, also provided rooflights. But those over the classroom had less measured effect than expected, and those over the workspaces were excessive in terms of light and solar heat.

The school was designed to be airtight in order to limit ventilation heat losses, but the result was poor air quality because there was no trickle or small high level ventilation option in the window design. Opening the large sliding windows often resulted in draughts. These draughts, and also down draughts from the closed windows, thwarted both the operation of the Trombe bench as an energy device and its use as a display area/worktop.

In the case of the rooflights, window design and Trombe bench, these problems could have been resolved better in the detail design. It showed the need for designers to understand where there might be conflicting elements and to explore their ideas with simple aids like models and artificial skies; and in the case of the novel Trombe bench where it was more difficult to anticipate the problems, through thermal modelling.

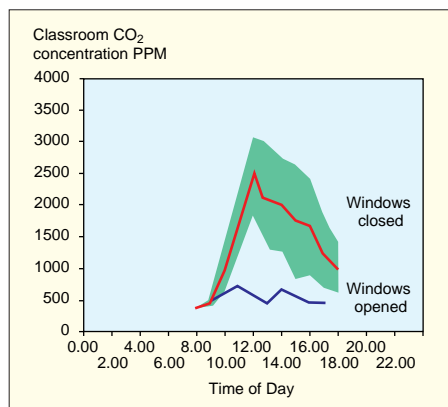
In general, simple uncomplicated designs that occupants can understand and operate easily, or that operate on their own, are most likely to succeed. The basic strategy for Looe of direct solar gain allied to thermal mass and fixed shading is an example of this.

### Conclusion

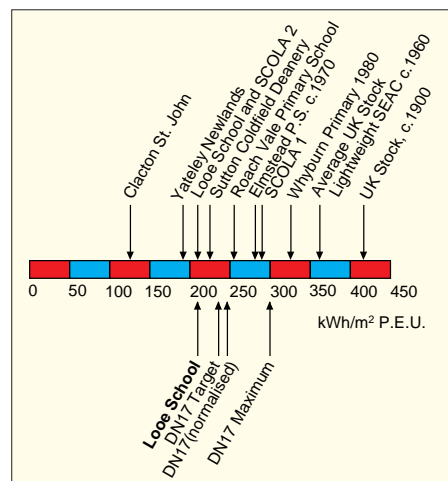
In comparison with other monitored schools, Looe has a very good energy performance. This performance was not achieved at extra cost because the cost was average, nor was it at the expense of amenity because the school is liked by those that use it. Solar gain allied with a traditional masonry construction proved to be a good strategy for providing a comfortable school which meets energy, environmental and educational criteria.

### Further reading

Further General Information Leaflets are being developed under the DOE's Energy Efficiency Best Practice programme.

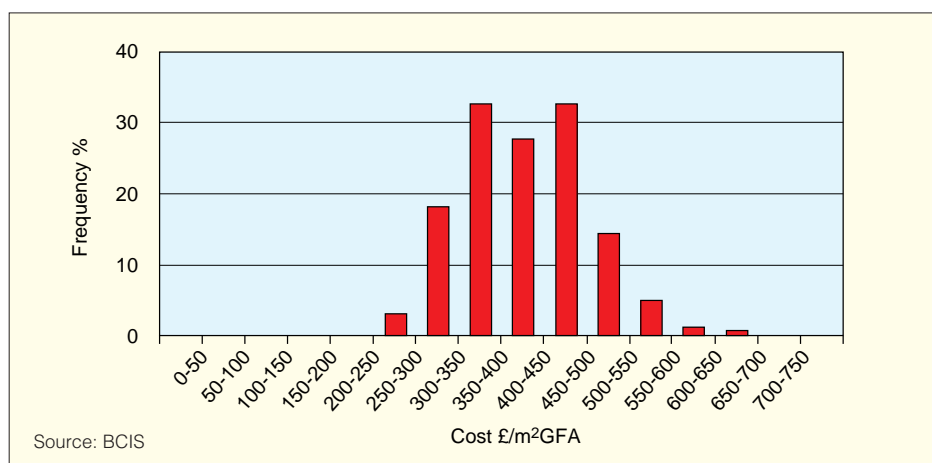


**Night-time air changes were low at 0.2 to 0.4 and average daytime ones varied between 1 and 2 with the windows closed which resulted in stuffiness. Window opening had a great effect on CO<sub>2</sub> levels but resulted in draughts because of the window design**



**Annual primary energy use in schools: Looe's 210 kWh/m<sup>2</sup> put it in front of other low energy schools**

To convert metered fuel into primary energy, conversion factors of 3.73 for electric energy and 1.08 for gas energy were used. These correspond to the approximate generation and transmission losses involved in these fuels.



**Primary school costs: Looe at £417/m<sup>2</sup> cost no more than the average school**

### Design criteria

Occupancy	Design 300 pupils Actual up to 347 pupils	Lighting	150 lux min 12 W/m <sup>2</sup>
Ventilation target	2.4 ach 30 m <sup>3</sup> /hr/p	Space heating	149 W/m <sup>2</sup>
		Hot water	35 W/m <sup>2</sup>

### Project data

<b>Dates</b>		<b>Building information</b>	
Design	Sept 1981	Volume	3600 m <sup>3</sup>
Tender	Mar 1982	Gross floor area	Ground floor 1290 m <sup>2</sup> First floor 84 m <sup>2</sup>
Built	Mar 1983 – Aug 1984	Gross roof area	Opaque roof 1407 m <sup>2</sup> Rooflights (DG) 79 m <sup>2</sup>
Monitoring	Feb 1987 – Jan 1988	Opaque wall area	659 m <sup>2</sup>
<b>Project team</b>		South facing window area (DG)	259 m <sup>2</sup>
Client	Cornwall County Education Committee	Non-south facing window area (SG)	77 m <sup>2</sup>
Architect	Cornwall County Architect's Department	South glazing/total glazed area	71%
Mechanical engineer	Andrew Weatherfoil Ltd	Window/wall area Classrooms	22%
Structural engineer	Jenkins & Potter	Whole school	15%
		Floor to ceiling height	2.4 m